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STRUCTURAL ASSEMBLY IN SPACE

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PART A

OVERVIEW

We wish to share with you our thoughts, accomplishments, and plans in large structures assembly. I will present an overview of our three-year study plan for Large Space Structures Technology (LSST). Ed Pruett (Essex Corporation) will report on the work Essex is performing this year in support of structural assembly definition and evaluation.

The role of man and machine in assembly operations has been given a great deal of consideration and debate over the last few years. Emphasis on one or the other as an assembly mode fluctuates each year.

We believe that, depending upon the packaging and orbital characteristics of a structure, as well as its complexity and mission requirements, there is a role in assembly for both man and machine. Figure 1 indicates a spectrum for mixing man and machine for any typical structure assembly. Totally manual operation appears at one end of the assembly spectrum, while totally automated operation appears at the other. Such operating factors as economics, nature of assembly tasks, and availability of technology, skills, etc. should direct design to some optimum man/machine mix for assembly.

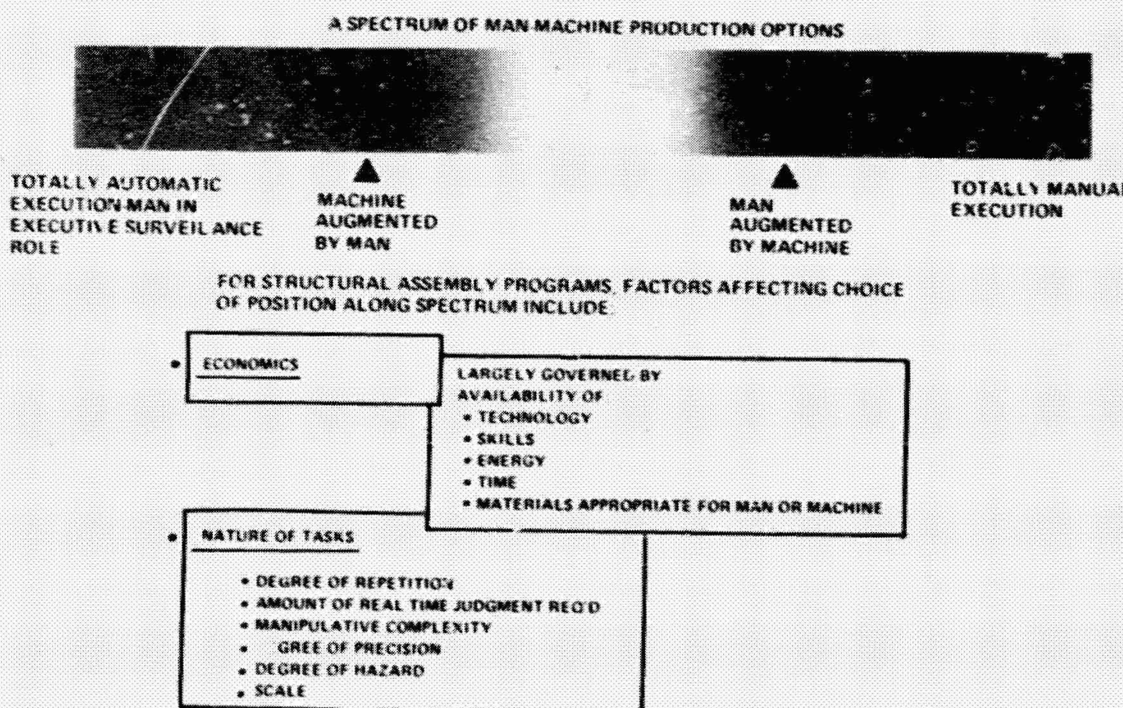


Figure 1 .../Machine Spectrum for Assembly

From Skylab we have demonstrated and proven that manned Extravehicular Activity (EVA) is a viabl technique for relatively simple one-time assembly functions. However, as depicted in figure 2, we recognize that as structure characteristics and requirements become more complex we must emphasize the role of remote/automated systems in structural assembly, using man as an overseer.

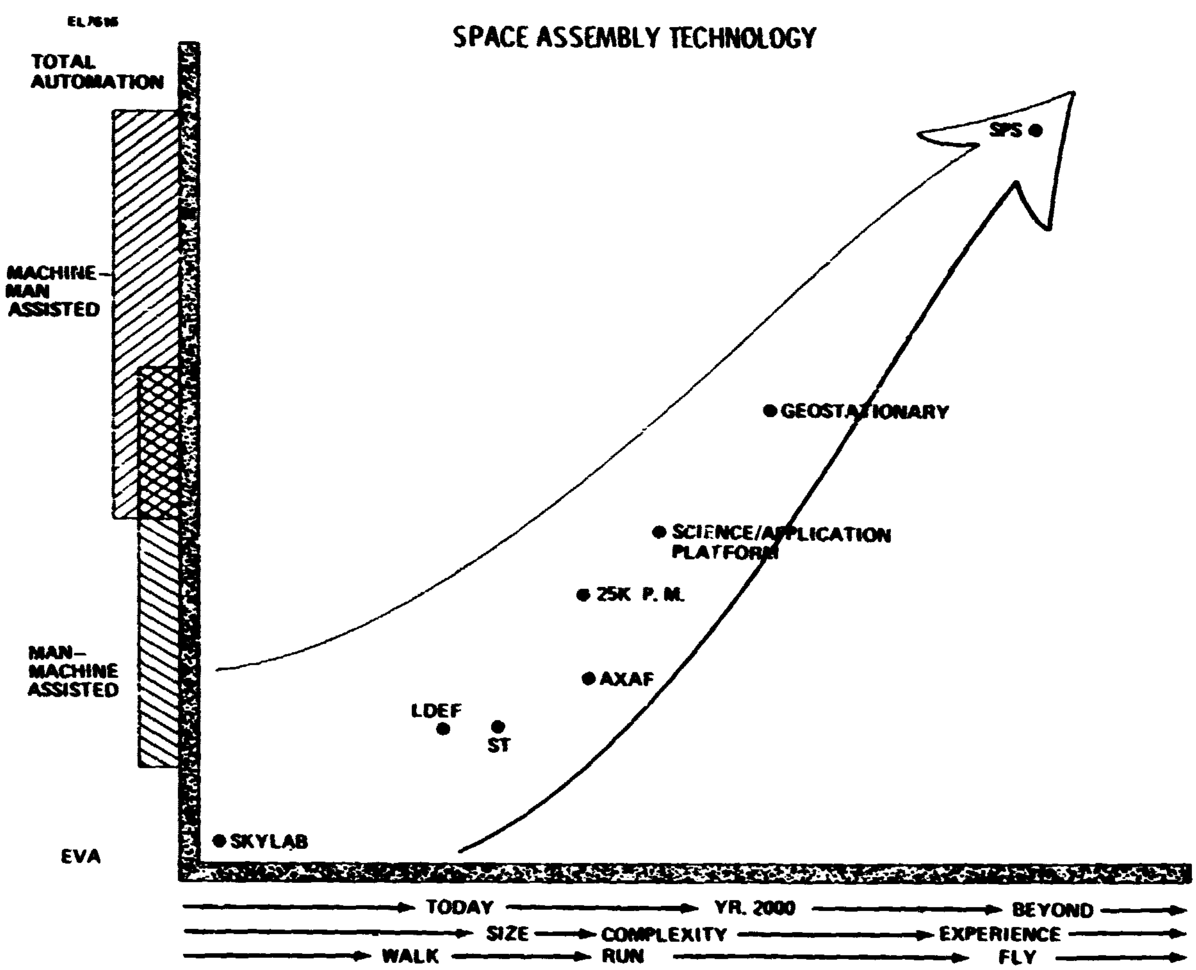


Figure 2 Man/Machine Role in Assembly

Manual assembly is very feasible (figure 3) when mechanical assembly methods remain simple or when the structure to be assembled is in close proximity to the Orbiter payload bay. However, assembly with manual crew aids becomes less efficient as construction moves to repetitious functions for large scale structures. Here, remote or automatic assembly aids may best perform the assembly fuctions.

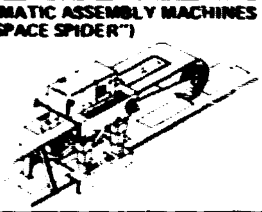
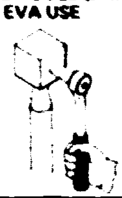
OPERATIONS/ASSEMBLY AIDS	CREW INVOLVEMENT	APPLICATION/ADVANTAGES
AUTOMATIC ASSEMBLY MACHINES (EG "SPACE SPIDER") 	• ESTABLISH INITIAL CONDITIONS • START AND STOP AUTOMATIC SEQUENCES • MONITOR EXECUTION, TROUBLE SHOOT HARDWARE AND SOFTWARE	• LARGE SCALE OPERATIONS • REMOTE OPERATIONS • LOW OR CONTROLLED CONSTRUCTION LOADS
FREE FLYING TELEOPERATORS 	• PILOT TRANSPORT VEHICLE • CONTROL MANIPULATOR ARMS • MONITOR SYSTEM STATUS, TROUBLE SHOOT HARDWARE, SOFTWARE	• REMOTE OPERATIONS • NON -REPETITIOUS OPERATIONS • TASKS WITH HIGH DEXTERITY REQUIREMENTS • CAN BE GROUND CONTROLLED
SHUTTLE-ATTACHED MANIPULATORS, CRANES, CHERRY PICKERS 	• PROVIDE STABLE STS PLATFORM FOR CONSTRUCTION OPERATIONS • OPERATE MANIPULATOR TO UNSTOW POSITION AND MATE STRUCTURAL ELEMENTS	• LOCAL (LOW EARTH ORBIT) CONSTRUCTION • CONTROLLED CONSTRUCTION FORCES • CONTINGENCY EVA POSSIBLE
HAND TOOLS & AIDS FOR EVA USE 	• EVA CREWMAN SERVES DIRECTLY AS SPACE CONSTRUCTION WORKER	• MINIMAL COST FOR EQUIPMENT DEVELOPMENT EXISTING CAPABILITY • HIGH FLEXIBILITY FOR UNFORSEEN TASKS • LOCAL CONSTRUCTION, SMALLER SCALE CONSTRUCTION

Figure 3 Orbital Assembly Aids and Crew Involvement

Our interest in the determination of efficient, cost effective structural assembly is manifested in a three year plan (figure 4). Through 1982 we will:

a. Continue to develop the cost analysis begun last year. This analysis is intended to establish a method for economically mixing large structure assembly techniques. It will also develop and evaluate procedures for assembling various large structures. We consider this analysis and its output, a working cost algorithm for assembly, to be our major study emphasis. The algorithm will be computerized and maintained such that an organization can determine the most cost effective method for assembling any defined structure.

- CONTINUE TO DEVELOP COST ANALYSIS - MAJOR STUDY EMPHASIS
- SHIFT FOCUS TO SPACE PLATFORMS & DEPLOYABLE STRUCTURES
- SHIFT EMPHASIS FROM MANUAL EVA OPERATIONS TOWARD REMOTE/AUTOMATED OPERATIONS
- CONTINUE TO SUPPORT ANALYSIS THROUGH SIMULATION - NEUTRAL BUOYANCY, ZERO-G, COMPUTER, OTHER PROGRAM SIMULATIONS
- CONTINUE TO DEVELOP & UPGRADE DEFINITION OF ASSEMBLY AIDS & CREW AIDS
- DEVELOP ASSEMBLY GUIDELINES DOCUMENT

Figure 4 Three-year Plan for LSST Operations

Figure 5 defines the functions required to complete the three-year plan. Typical structure scenarios, based on benchmark large structures, are being examined and expanded in the area of assembly. Data collected from documentation and simulation feed into functional analyses for each scenario. From such analyses can be determined crew tasks and associated times, as well as assembly and crew aid requirements. Such data can be converted to number of Space Transportation System (STS) flights to determine manual assembly costs, and definition of assembly and crew aids. This can be compared to other cost factors determined through further analysis. The resulting cost algorithm will provide a useful tool for defining the proper mix of functions for man and machine.

b. Our study emphasis previously has been on erectables. Since we have established some definition on erecting structures through manual EVA operations, we will concentrate on deployable structures, with some emphasis on fabricated assemblies. In line with LSST Program Office interests we will address space platforms in lieu of antennas.

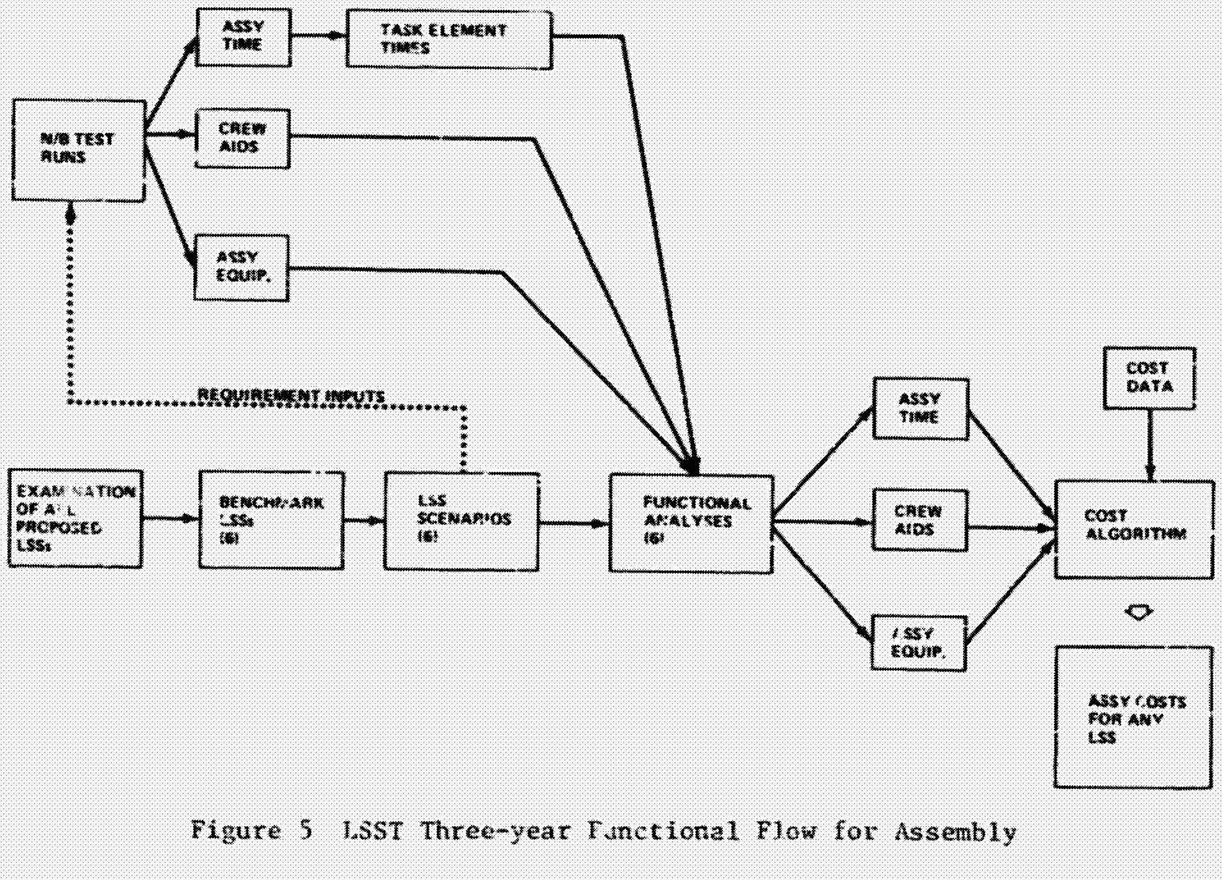


Figure 5 LSST Three-year Functional Flow for Assembly

c. We have established an initially adequate amount of baseline data for manual EVA assembly. We need to better understand the specifics of remote/automated assembly in order to determine proper man/machine mixes for building structures. Therefore, emphasis will shift toward remote assembly, though we will continue to evaluate manual techniques as required.

d. We have performed and will perform various relevant neutral buoyancy assembly simulations as defined in figure 6. Our analysis will continue to be supported through underwater simulation. More realistic simulations will be possible with our new cargo bay mockup including a soon-to-be-delivered functional Remote Manipulator System (RMS). However, new simulation modes will be considered, since neutral buoyancy testing has several inherent shortcomings. Such simulation methods as zero-g (KC-135 Aircraft) and computer-aided techniques will be investigated. We also will continue to monitor those simulations performed for other programs which may supply relevant data toward the analysis.

√ TEST AND EVALUATION OF LaRC NESTABLE COLUMN ELEMENTS WITH LOCKHEED-SUPPLIED JOINTS/UNIONS.

√ ASSEMBLY OF TETRAHEDRAL CELL USING SELECTED BEAMS AND ROCKWELL-SUPPLIED JOINTS

√ NEUTRAL BUOYANCY EVALUATION OF ROCKWELL-SUPPLIED EVA ELECTRICAL CONNECTOR.

√ CONTINUED EVALUATION OF A VARIETY OF POSSIBLE ELEMENTS, JOINTS AND ASSEMBLY TECHNIQUES.

√ EVALUATION OF 36-ELEMENT STRUCTURE BY MIT

√ ON-ORBIT MAINTENANCE OF SPACE TELESCOPE

Figure 6 Neutral Buoyancy Activities for FY79-FY80

e. As a part of the analysis and simulation activity we will continue to define and develop assembly aids and crew aids required to assemble large structures. We will consider those aids available through STS, but will not limit ourselves to them. We understand that assembly can occur either in the payload bay or from a remote site. Therefore, assembly aid requirements may vary from structure to structure.

f. An assembly guidelines document will be generated from data collected from analysis, simulations, and early STS flights. Such a document will assist in the planning and development of the assembly techniques.

Figure 7 describes the schedule for meeting the six functions listed above.

A detailed explanation of the study, as well as the accomplishments for the year, are described in Part B.

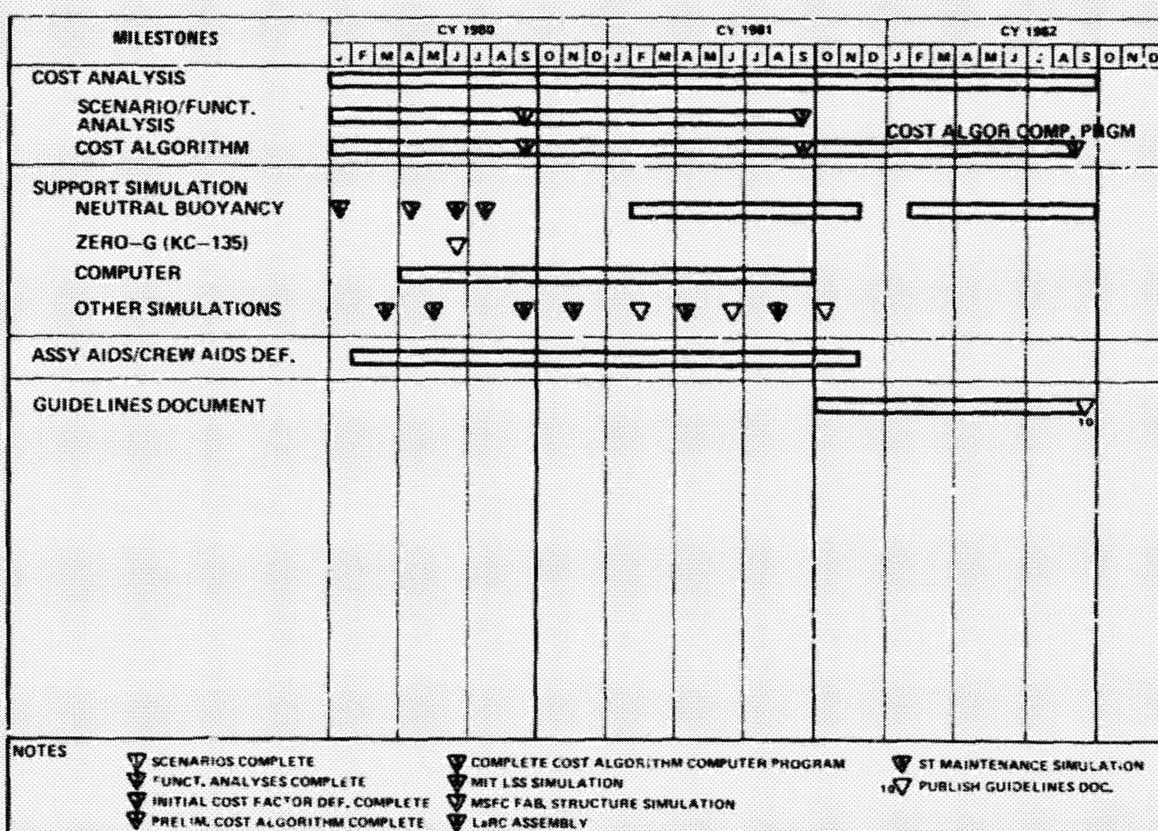


Figure 7 Assembly Three-year Schedu

In summary, let us address what we have learned about assembly in space (figure 8). From Skylab we know that man can perform large scale planned and unplanned operations. Both erectable and deployable assembly have been successfully demonstrated.

We further have demonstrated in a water environment, that under controlled conditions an EVA subject with minimal crew aids (dual handrails) can manipulate masses up to 17,000 lb.

Underwater simulations of payload-related EVA tasks have demonstrated that a crewman can perform contingency EVA operations. However, this is dependent upon early planning in design for manned participation in such contingencies.

Neutral buoyancy simulations investigating the transport, positioning, and assembly of large structural elements have simulated assembly with unaided one and two man operations, EVA operations with manipulator assistance, and EVA operations with small piloted vehicle support. From such tests we have determined that EVA assembly is possible and feasible. Results indicate that, even though one crewman can accomplish assembly, it is more efficient with two men and in some cases with machine aid.

WHAT HAS BEEN DONE TO HELP US LEARN ABOUT ASSEMBLY IN SPACE?

ACTIVITY	RESULTS
√ SKYLAB REPAIR OPERATIONS	ESTABLISHED THAT CREWMEN CAN PERFORM LARGE SCALE PLANNED AND UNPLANNED OPERATIONS
√ EXPERIMENTS WITH MANUAL MANIPULATIONS OF VERY HIGH MASSES	NB SUBJECTS MANIPULATE 17,000 LB. MASSES
√ NEUTRAL BUOYANCY SIMULATIONS OF SPACELAB PAYLOAD-RELATED EVA TASKS	• CREWMAN PERFORM CONTINGENCY EVA OPERATION IN PAYLOAD BAY • PLAN FOR CREW INVOLVEMENT EARLY IN DESIGN
√ NEUTRAL BUOYANCY TRANSPORT, POSITIONING AND ASSEMBLY OF LARGE STRUCTURAL ELEMENTS (MSFC & LaRC) • UNAIDED ONE AND TWO MAN EVA OPERATION • EVA OPERATION WITH MANIPULATOR ASSISTANCE • EVA OPERATION WITH SMALL PILOTED VEHICLE SUPPORT	• EVA ASSEMBLY POSSIBLE; TWO MAN, OR MACHINE AIDED TASK PREFERRED TO ONE MAN OPERATION • CREW WORKSTATION/RESTRAINTS REQUIRED: CREW MOVEMENT IS COSTLY • STRUCTURAL ELEMENTS MUST HAVE FLEXIBILITY DURING ASSEMBLY • ASSEMBLY TIME FOR TETRAHEDRAL CELL APPROXIMATELY 1/4 HOUR • CONSIDER CREW FOR NONREPETITOUS TASKS, CONSIDER MACHINE FOR ERECTING/DEPLOYING STRUCTURES

Figure 8 Lessons Learned in Large Structure Assembly

It is important to note that assembly time is greatly reduced, and hardware damage is kept to a minimum when the crewman has a proper workstation, which includes foot restraints, and continuous visual and manipulative access to the components being assembled. It should also be emphasized that there must be flexibility among structural elements during the actual assembly operation. Unions on columns or beams which do not allow some play during assembly are strong candidates for damage.

We have found that a two-man EVA team can assemble a tetrahedral cell in about 15 minutes when properly restrained and with minimized crew activity. However, the water environment and its inherent drag on large volume, low mass equipment may make this a very conservative number. Use of other simulation modes may demonstrate that this number can be reduced.

Lastly, we should emphasize that manual EVA is an acceptable mode for nonrepetitious assembly tasks. However, if repetitious tasks are required or if assembly occurs remotely from the Orbiter cargo bay, we should consider remote controlled assembly equipment for large scale construction.

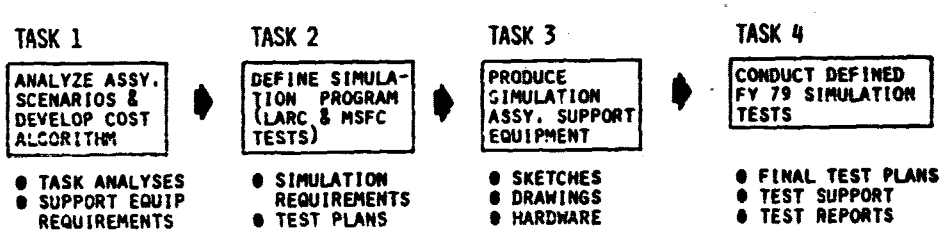
PART B - RESULTS TO DATE

BACKGROUND AND SCOPE

Essex Corporation is currently supporting MSFC's LSST program under a contract entitled "On-Orbit Assembly of Large Space Structures" (NAS8-32989). The overall purpose of the effort is to learn more about the cost for assembling a large structure by EVA crewmen working unaided or using available assembly aids such as the manned maneuvering unit (MMU), shuttle remote manipulator system (RMS), or a teleoperator. Although the total cost for a large structure would include costs for such activities as research and development, ground fabrication, checkout, and ground support, the cost for assembling a platform or antenna in space will be a major cost driver and should be considered when evaluating any proposed LSS as a candidate for further development and flight. The work being performed by Essex is aimed at developing assembly cost data so the assembly costs for any proposed structure can be estimated before any significant development expenses are incurred. Although embryonic in nature, this work could eventually have a tremendous impact on the selection of proposed structures for further evaluation.

CONTRACT TASKS

The two major activities being performed within the contract are (1) development of a cost algorithm for predicting assembly costs (Task 1), and (2) support of the LSS testing effort at MSFC's Neutral Buoyancy Simulator (Tasks 2, 3 & 4). The four tasks and their major outputs are shown below.



Task 1 is by far the most difficult and consuming of the four tasks. In this task, several LSS scenarios are being prepared that describe a wide range of structure configurations and assembly operations. These scenarios are used to develop more detailed functional analyses that describe the assembly steps and the hardware required to support the assembly task. The seven Task 1 subtasks are listed below.

SUBTASK

1.1 Develop Generic Assembly Scenarios
1.2 Define Assembly Tasks
1.3 Define Support Equipment
1.4 Develop Equipment Performance Requirements
1.5 Develop Cost Algorithm
1.6 Identify Cost Parameters
1.7 Determine Costs for the Six LSSs Studied and Other Proposed LSSs to Evaluate Cost Options

In Task 2, the neutral buoyancy test program is being defined in terms of the simulation requirements and support hardware required for the tests. Preliminary test plans are being prepared for evaluation of two types of joints and two types of columns. Preliminary test plans for evaluation of a 36 element structure to be provided by the Massachusetts Institute of Technology (MIT) are also being prepared.

The purpose of Task 3 is to provide hardware needed during the neutral buoyancy tests but not provided by MSFC or some other NASA center. This includes handrails, foot restraints, assembly fixtures, and data recording equipment.

In Task 4, the simulation test plans are updated to reflect the as-built hardware configurations and any additional procedural changes. During the tests Essex provides a test conductor as well as data recorders and test observers.

PROJECT STATUS

The major output from Task 1 is the cost algorithm for predicting assembly costs. To develop this algorithm, several supporting activities have been started that will provide input data to the algorithms such as the wide range of crew and aided assembly tasks and the cost for providing various labor and hardware elements. Although the cost algorithm is not complete, many of these supporting activities are near completion.

Five assembly scenarios have been prepared that describe the erection, deployment, and fabrication tasks for the structures listed below. These structures were selected not because of their probability of further development and flight but because of the wide range of assembly tasks they included that should be reflected in the algorithm.

- LaRC/RI Pentahedral Area Nodal Mount (Ref. 1)
- JSC/MDAC Single Trapezoidal Box with Nested Pallets (Ref. 2)
- JSC/MDAC Telescopic Spine (Ref. 2)
- MSFC Space Fabricated Platform (Ref. 3)
- MSFC 50m Deployable Antenna (Ref. 4).

Each of these scenarios includes the following major headings:

1.0 Outline
2.0 Description of Structure
3.0 Packaging Plan
4.0 Major Assembly Steps
5.0 Assembly Equipment and Aids
6.0 Problem Areas.

These sections describe the major activities that might impact total cost for structure assembly from launch through component deployment and assembly to scientific instrument installation and checkout.

Functional analyses that describe these structures in more detail have also been prepared. These documents describe in more detail the individual assembly tasks, the crewmen and their locations, the crew aids and LSS hardware required to perform the task, and the time required.

Individual cost elements such as assembly fixtures, handrails, or remote manipulators have been identified and are presented in Table 1. The specific costs for each of these elements is currently being assessed in terms of dollar cost, volume, weight, etc. The costs for these items will not remain static, and some will be entirely structure-dependent. Any uncertainties associated with the individual cost elements are being recorded in addition to the projected cost per unit, flight, pound, foot, hour, etc.

Table 1 - LSS Assembly Cost Elements

(1) Labor
- EVA Astronauts
- IVA Support Crew
  - o RMS Operator
  - o Assy Coordinator
- Ground Support Crew
- Training Time, Materials & Development
- Development Simulations

(2) LSS Hardware
- LSS Beams or Columns
- Utility Conduits & Junction Boxes
- Experiment Pallets
- LSS Subsystem
  - o Attitude Control System
  - o Power System
  - o Thermal System
  - o Sensors
- Alignment Tools
- Jigs & Fixtures
- Crew Tools
- Crew Aids
  - o Handrails
  - o Foot Restraints
  - o Tethers
  - o Lights
  - o Cameras & Monitors
  - o Portable Work Stations
- RMS & End Effectors
- MMU
- Materials (Sheet Stock, Welding Materials, etc.)
- Fasteners

(3) Crew Support Equipment
- Pressure Suits
- Suit Resupply
- Suit Stowage & Handling
- Food & Other Consumables
- Time On Orbit
- Assy Procedures, Checklists, Diagrams
- Communication Equipment

(4) Flight Operations
- No. of Flights
- Duration of Flights
- No. of Onboard Crewmen
- No. of Ground Crewmen
- No. of EVAs
- EVA Duration
- Orbital Maneuvers

(5) Other
- Assy Error Probability
- Assy Destruction Probability
- Power (Aug & Peak)
- Hydraulics, Pneumatics
- Ground Prep. Time (Packaging)
- Development Costs

Development of the initial cost algorithm should be completed by February, 1980.

In Task 2, a generic simulation test plan was prepared for distribution by MSFC to contractors and other NASA centers who are planning test activities in MSFC's Neutral Buoyancy Simulator. This plan identifies the step-by-step task descriptions required, the data recording capabilities and other information needed by personnel not familiar with the MSFC test procedures.

Additionally, preliminary test plans were prepared for evaluation of the LaRC snap joint/unions, Rockwell ball and socket joints, and the 18 ft and 30 ft columns (NB-18A, B and C).

In Task 3 a video tape recording system was provided for recording the test runs. This system has been tremendously useful for analyzing the crew assembly operations after the test runs.

A manned maneuvering unit (MMU) mockup is also being designed for use in the simulator to support the LSS test runs.

In Task 4 six member tetrahedral cells were assembled 38 times during 21 test runs. During the runs Essex provided a test conductor, data collectors, and test observers. Final test plans were provided prior to each run, and quick-look test reports were prepared after each run. Final test reports were also prepared describing the results of all the tests. Figures 9 through 14 illustrate the assembly of the tetrahedral cell from initial conditions through installation of the simulated equipment module (SEM) at the apex at the end of the run. Figures 15 and 16 show the two joints evaluated.

MAJOR STUDY OUTPUTS

Three study outputs are presented below in addition to the results already discussed in the above project status summary. These study outputs are:

- Neutral buoyancy test results
- Task element times
- Status of cost algorithm.

NEUTRAL BUOYANCY TEST RESULTS

The results of the 21 neutral buoyancy test runs to evaluate the snap joint/unions, ball and socket joints, and 18 ft and 30 ft columns are presented in detail in the quick-look and final test reports. However, the following paragraphs summarize the results and conclusions.

Assembly Time - The lowest assembly times for unaided operations (no RMS or MMU) for the 18 ft columns were on the order of 30 min for the six element structure. The best assembly times using the simulated RMS for column handling and a simulated MMU for crew translation for three union/column combinations are listed below.

	Time (Min)
• Ball and Socket w/ 30 ft Columns	10.6
• Ball and Socket w/ 18 ft Columns	11.1
• Snap Joint w/ 18 ft Columns	14.5

This represents an evaluation of two types of unions and columns from dozens of possible alternatives. Obviously no firm hardware tradeoff data should be drawn from these preliminary tests. However, it does appear that the assembly operation is possible with existing STS equipment and EVA technology and the assembly time for a six element structure is in the 15-30 min. range.

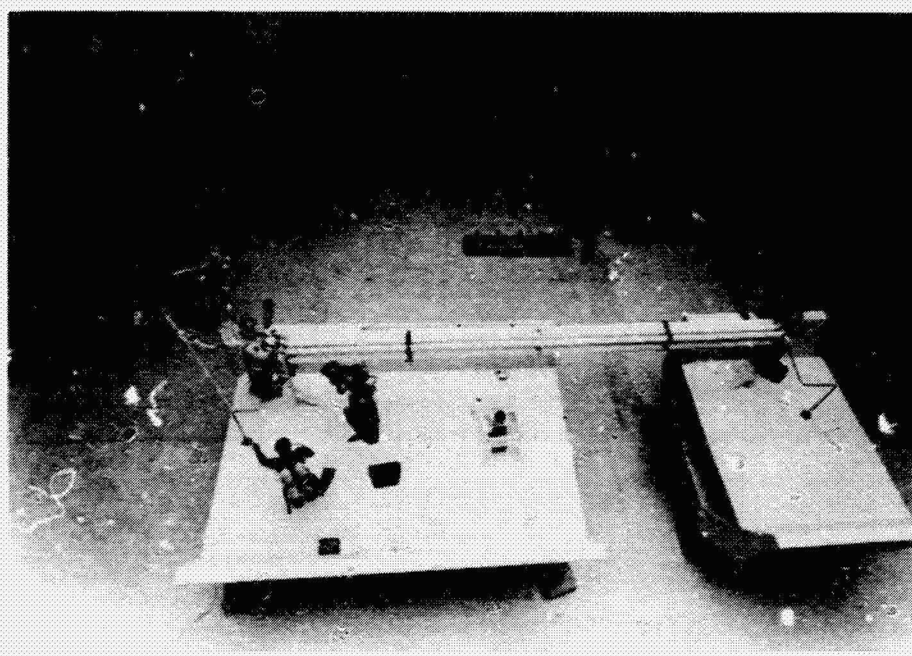


Figure 9 - Test Setup for LSS Tetrahedron Assembly

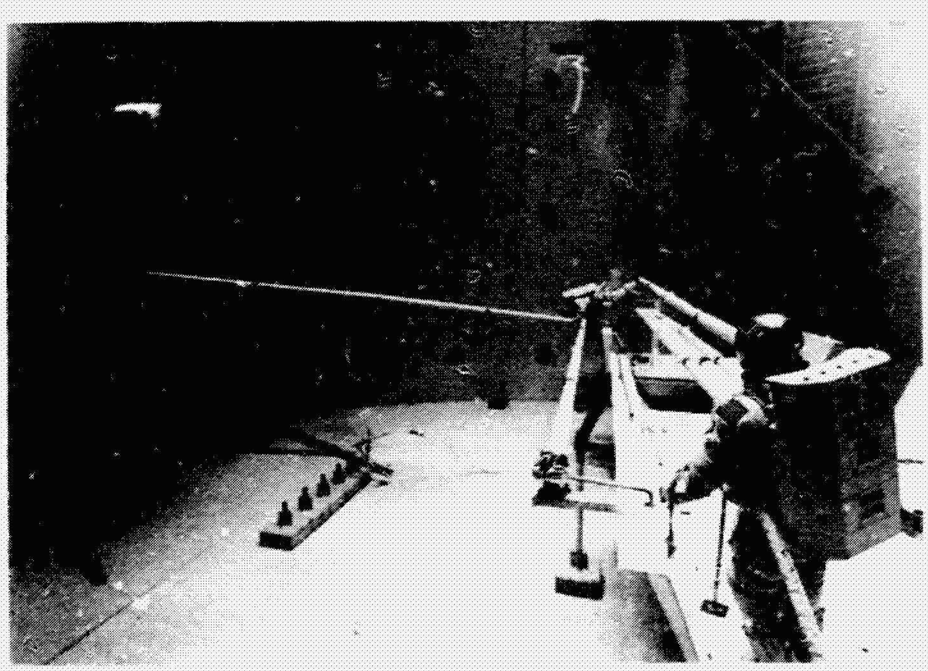


Figure 10 - Installation of Second Column

C-4

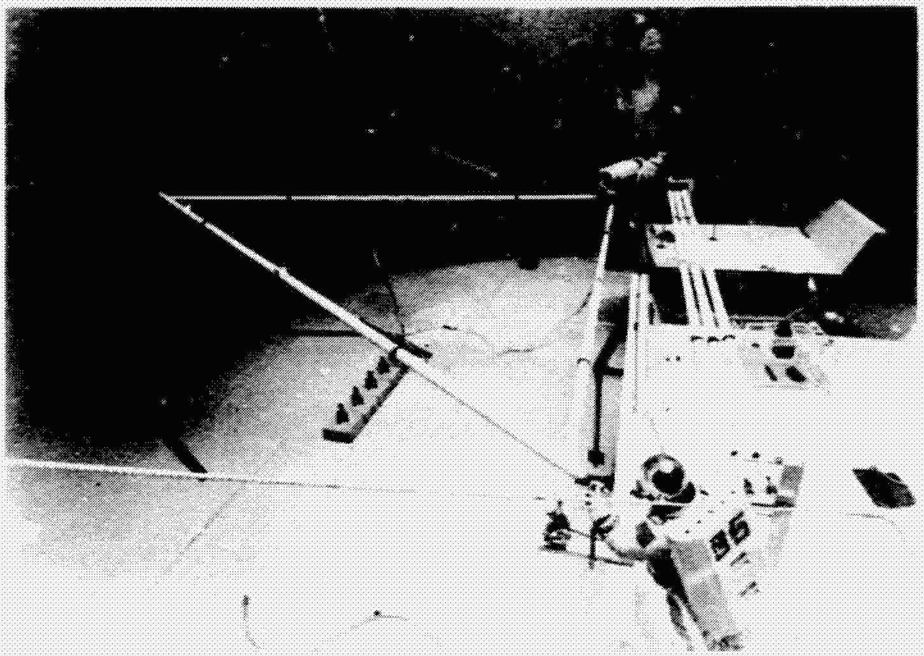


Figure 11 - Completion of Base Triangle

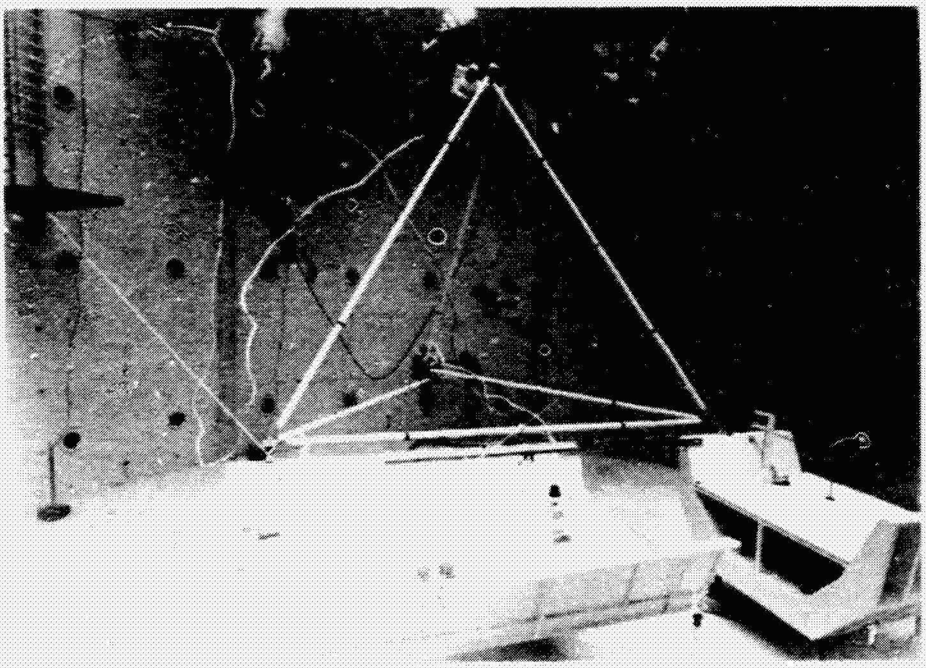


Figure 12 - Completion of Tetrahedron Structure

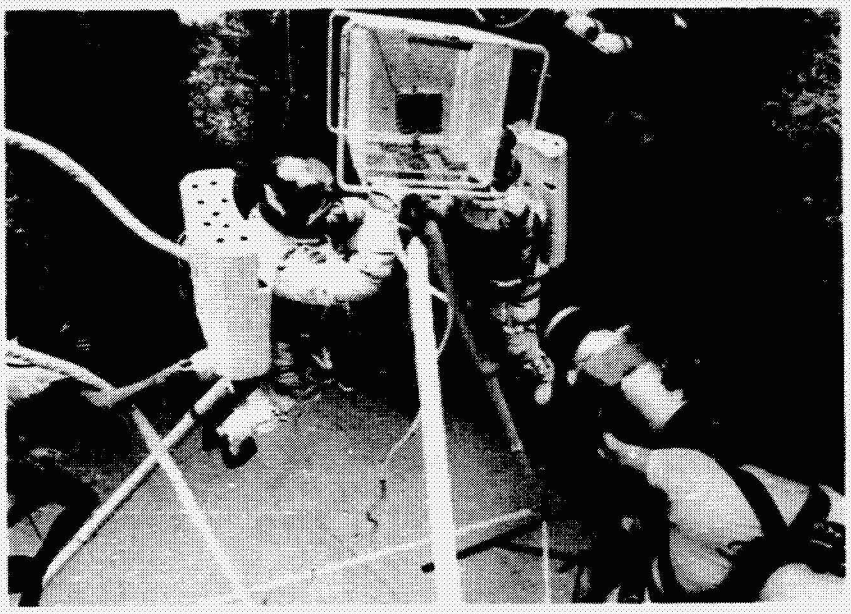


Figure 13 - Installation of Simulated Equipment Module

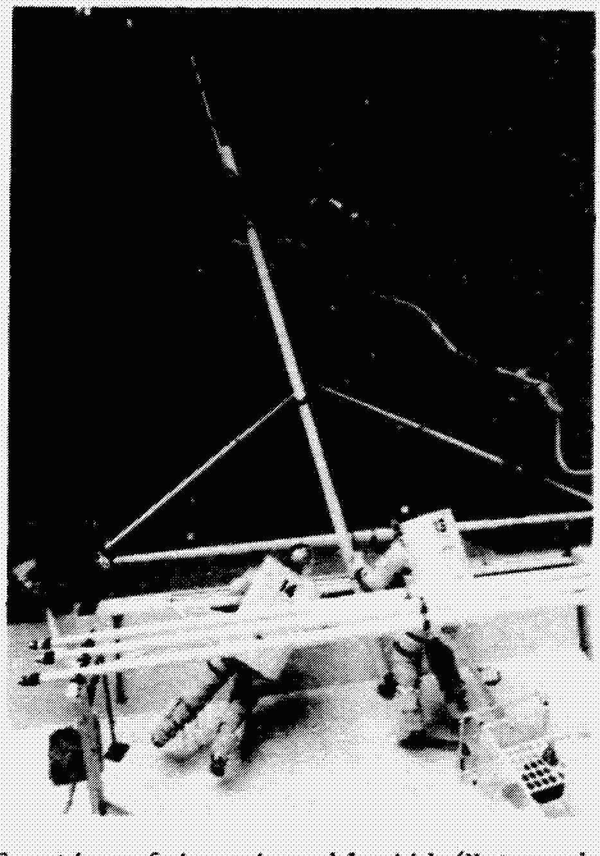


Figure 14 - Erection of Apex Assembly Aid (Not used on all runs)

Figure 15 - Ball and Socket Joint

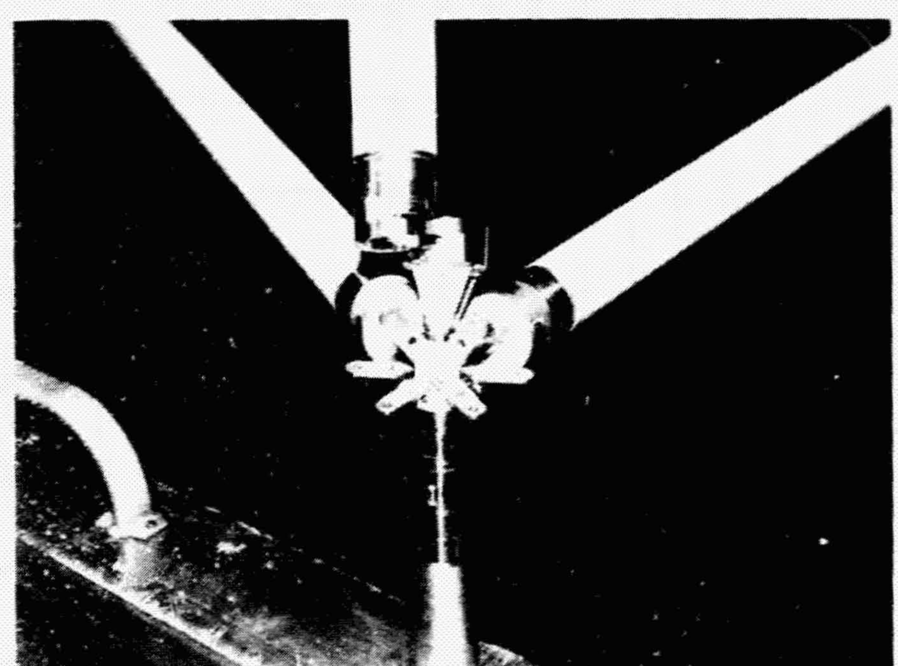


Figure 16 - Snap Joint/Union

Ease of Operations - Subjectively, the crew preferred the ball and socket joints. It appeared from the run times that more training was required for the snap joint/unions for the crew to become proficient at mating the unions.

Support Equipment Needed - The snap joint/union was more easily operated when a positive crew restraint such as a foot restraint was used. The crew could easily use the ball and socket joint without the aid of a foot restraint.

Reliability - The snap joint/union often could not be mated by the crewman because of column or assembly fixture misalignment. This required that the utility divers make the connection or verify that the crewman had successfully made the connection. This was not true for the ball and socket joints.

TASK ELEMENT TIMES

The evaluation of video tapes from the LSS test runs and some of the Space Telescope test runs revealed 10 major task categories. All the crew operations can be described in terms of these task categories and 83 subtask categories or individual task elements. The 10 task categories are:

- Remove
- Translate
- Position Body
- Ingress
- Egress
- Attach
- Transfer
- Mate
- Verify
- Hand Tool Use

The task elements shown in Table 2 can be used to describe all the crew operations observed in the LSS and Space Telescope test runs. The Space Telescope runs were used to include large module handling and the use of tools which were not observed during the LSS runs.

The task element data presented in these charts can be used along with detailed assembly procedures for any proposed structure to estimate the structure assembly time. The validity of the task element time data will be determined by comparing estimated versus actual assembly times for LSS structures assembled in the neutral buoyancy simulator in the future (e.g., the MIT test scheduled for January, 1980).

STATUS OF COST ALGORITHM

The initial cost algorithm for predicting total LSS assembly costs is currently a collection of independent sets of data with no connecting logic. The major parts of the algorithm are the task element times, cost elements, and functional analyses that define support hardware the labor requirements. It is anticipated that the initial algorithm will be completed in February, 1980 and will be continually updated and expanded throughout the LSST program.

Table 2 - LSS Assembly Task Element Times

TASK ELEMENT		TIME (sec)
1.0	REMOVE	
1.1	Equipment Module from Receptacle (3'x3'x2' - push/pull, no latch)	21
1.2	Union from Box	7
1.3	Union from Post	NA
1.4	Pin from Post	NA
1.5	Column from Rack	8
1.6	Waist Tether from Handrail	12
1.7	Wrist Tether from Union	6
1.8	Wrist Tether from Equipment Module	8
1.9	Module from Base Plate Pins - Critical Alignment	15

TASK ELEMENT		TIME (sec)
2.0	TRANSLATE	
2.1	Along Sill 10 ft.	24
2.2	Along Sill 20 ft.	49
2.3	Over Sill from Outrigger	21
2.4	Over Sill from Cargo Bay	11
2.5	Up Assy Aid Pole 15 ft.	40
2.6	Down Assy Aid Pole 15 ft	22
2.7	Up Assy Aid Pole 15 ft. with Equipment Module (3'x3'x1-1/2')	44
2.8	20 ft. with Columns Using MMU	NA
2.9	30 ft. with Columns Using MMU	NA
2.10	20 ft. Using MMU	NA
2.11	30 ft. Using MMU	NA
2.12	Body 90°	10
2.13	Body 180°	20
2.14	10 ft. Along Straight Handrail	12
2.15	10 ft. Along Curved Handrail	15

TASK ELEMENT		TIME (sec)
3.0	POSITION BODY	
3.1	To Ingress Foot Restraint	19
3.2	To Ingress Leg Restraint	29
3.3	To Attach Waist Restraint	NA
3.4	To Attach or Verify Union Connection	22
3.5	To Verify Column Connection	23
3.6	To Receive Union	NA
3.7	To Receive Column in Leg Restraint	7
3.8	To Receive Column in Foot Restraint	NA
3.9	To Receive Column w/o Leg or Foot Restraint	17

TASK ELEMENT		TIME (sec)
4.0	INGRESS	
4.1	Foot Restraint Using One Handrail	21
4.2	Foot Restraint Using Two Handrails	13
4.3	Leg Restraint Using One Handrail	37
4.4	Leg Restraint Using Two Handrails	NA

TASK ELEMENT		TIME (sec)
5.0	EGRESS	
5.1	Foot Restraint Using One Handrail	8
5.2	Foot Restraint Using Two Handrails	5
5.3	Leg Restraint Using One Handrail	14
5.4	Leg Restraint Using Two Handrails	NA

TASK ELEMENT		TIME (sec)
6.0	ATTACH	
6.1	Waist Tether to Handrail with Foot Restraint	16
6.2	Waist Tether to Handrail w/o Foot Restraint	20
6.3	Union to Own Wrist Tether	17
6.4	Union to Other Crewman's Wrist Tether	NA
6.5	Waist Tether to SEM	12
6.6	Module to Clothesline Hook	12
6.7	Wrist Tether to Clothesline Module	15

Table 2 - LSS Assembly Task Element Times (Continued)

TASK ELEMENT	TIME (sec)
7.0 TRANSFER	
7.1 Assy Aid to Vertical Position (1 or 2 crewmen)	33
7.2 Assy Aid to Locked Position	26
7.3 18 ft. Column 10° Using Foot Restraint	12
7.4 18 ft. Column 60° Using Foot Restraint	49
7.5 18 ft. Column 60° Using No Foot Restraint	43
7.6 30 ft. Column 10° Using Foot Restraint	NA
7.7 30 ft. Column 60° Using Foot Restraint	NA
7.8 30 ft. Column 60° Using No Foot Restraint	NA
7.9 Module on Clothesline 20 ft.	35

TASK ELEMENT	TIME (sec)
8.0 MATE	
8.1 Assy Aid Clamp to Pole	56
8.2 Union to Pedestal - Critical Alignment	28
8.3 Column to Union - Critical Alignment	31
8.4 Equipment Module to Union-Critical Alignment	95
8.5 Union to Pedestal - Coarse Alignment	23
8.6 Column to Union - Course Alignment	9
8.7 Equipment Module to Union-Gross Alignment	34
8.8 Union to Assy Pole Clamp	55
8.9 Union to Column - Course Alignment	9
8.10 Tighten Ball Joint Jam Nut	12
8.11 Module to Base Plate Pins-Critical Alignment	90

TASK ELEMENT	TIME (sec)
9.0 VERIFY	
9.1 Assy Aid Pole Clamp Secure	30
9.2 Assy Aid Union Clamp Secure	35
9.3 Union Mated to Pedestal - Critical Alignment	20
9.4 Column Mated to Union - Critical Alignment	36
9.5 Union Mated to Pedestal - Gross Alignment	NA
9.6 Column Mated to Union - Gross Alignment	NA

TASK ELEMENT	TIME (sec)
10.0 HAND TOOL USE	
10.1 Grasp Tool	17
10.2 Position Ratchet on Bolt	9
10.3 30° Ratchet Stroke*	3
10.4 45° Ratchet Stroke*	4
10.5 90° Ratchet Stroke*	6
10.6 180° Ratchet Stroke*	10
10.7 Release Bolt Clip	20
10.8 Engage Bolt Clip	25
10.9 Translate 2' Between Bolts	10

*Less than 5 ft-lbs. torque

SUMMARY

The major activities remaining in the existing Essex contract are additional support of the LSS tests planned for January, 1980 and completion of the initial cost algorithm. These activities as well as the tasks already completed will be described in a report due in February.

REFERENCES

1. Final Review, Erectable Space Sciences and Applications Platform Study, SSD 79-0029, February 15, 1979, Contract NAS1-15322.

2. Deployable Orbital Service Platform Conceptual Systems Study, Final Review, MDC G7593, February 14, 1979.

3. Systems Definition Study for Shuttle Demonstration Flights of Large Space Structure, Final Review, Grumman Report No. N55-LS-RP0020, April 1979, Contract NAS8-32390.

4. Final Report, Deployable Antenna Phase A Study, May 15, 1979, Contract NAS8-32394.